

Be/C Surface Mixing Kinetics Effects Experiments in Support of ITER

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Outline of proposed work

- **Motivation**
- **Work Proposed**
- **Description of *IMPACT* and *ARIES* facilities: capabilities**
- **Budget and Timeline**

Motivation for Be/C mixing work

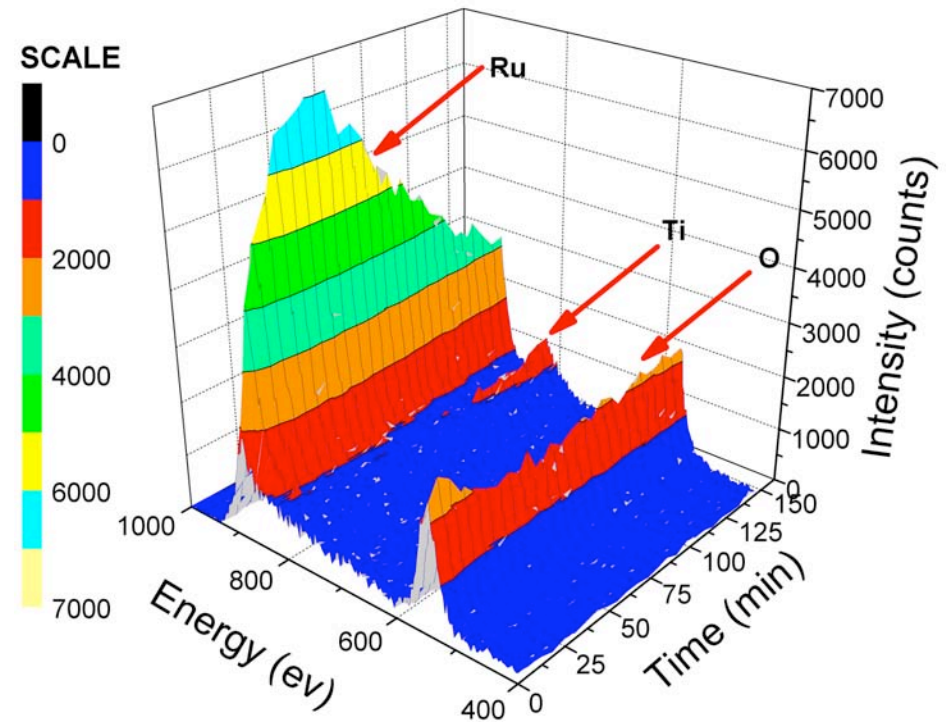
- Experiments in the PISCES-B facility show synergistic mechanisms between implanted Be and graphite surfaces.
- For example, even small Be-impurity concentrations in the plasma drastically suppress carbon erosion. These mixed Be-C layers lead this reduction (both physical and chemical erosion) and influences the deuterium recycling and co-deposition properties of the plasma-facing materials.
- Experiments at Argonne and Sandia/Livermore will focus on two questions:
 - What mechanism(s) are responsible for carbon erosion reduction when bombarding a mixed Be-C surface (i.e. role of oxygen or implanted deuterium)?
 - What is the effect of a mixed Be/C surface on D surface kinetics?

IMPACT: fully-operational facility

- **PRIME and the IMPACT experiment has been a very active facility since arrival of in-situ metrology in June 2004.**
- **Measurements of mixed-material surface kinetics evolution under heavy-ion (Xe^+ , Sn^+) bombardment for various applications:**
 - EUV lithography applications (Ru and Pd-based thin-film materials)
 - Liquid Sn work (specifically experiments at near-threshold levels)
- **Addition of lithium ion source for fundamental and applied studies:**
 - EUV lithography applications: in-situ monitoring of lithium and oxygen evolution under Li atom and charged-particle bombardment
 - Li self-sputtering studies in solid and liquid states with in-situ monitoring of the surface (role of oxides and impurities on erosion)
- **Newly installed low-energy ion source will be used for D-based experiments at near-threshold energies: 10-100 eV with current densities near 0.5 mA/cm²!**

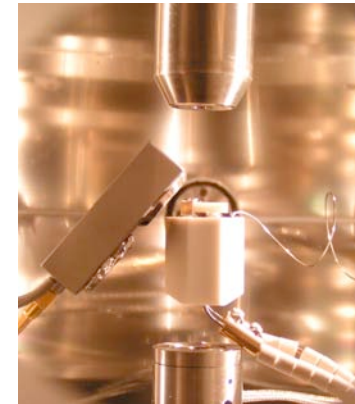
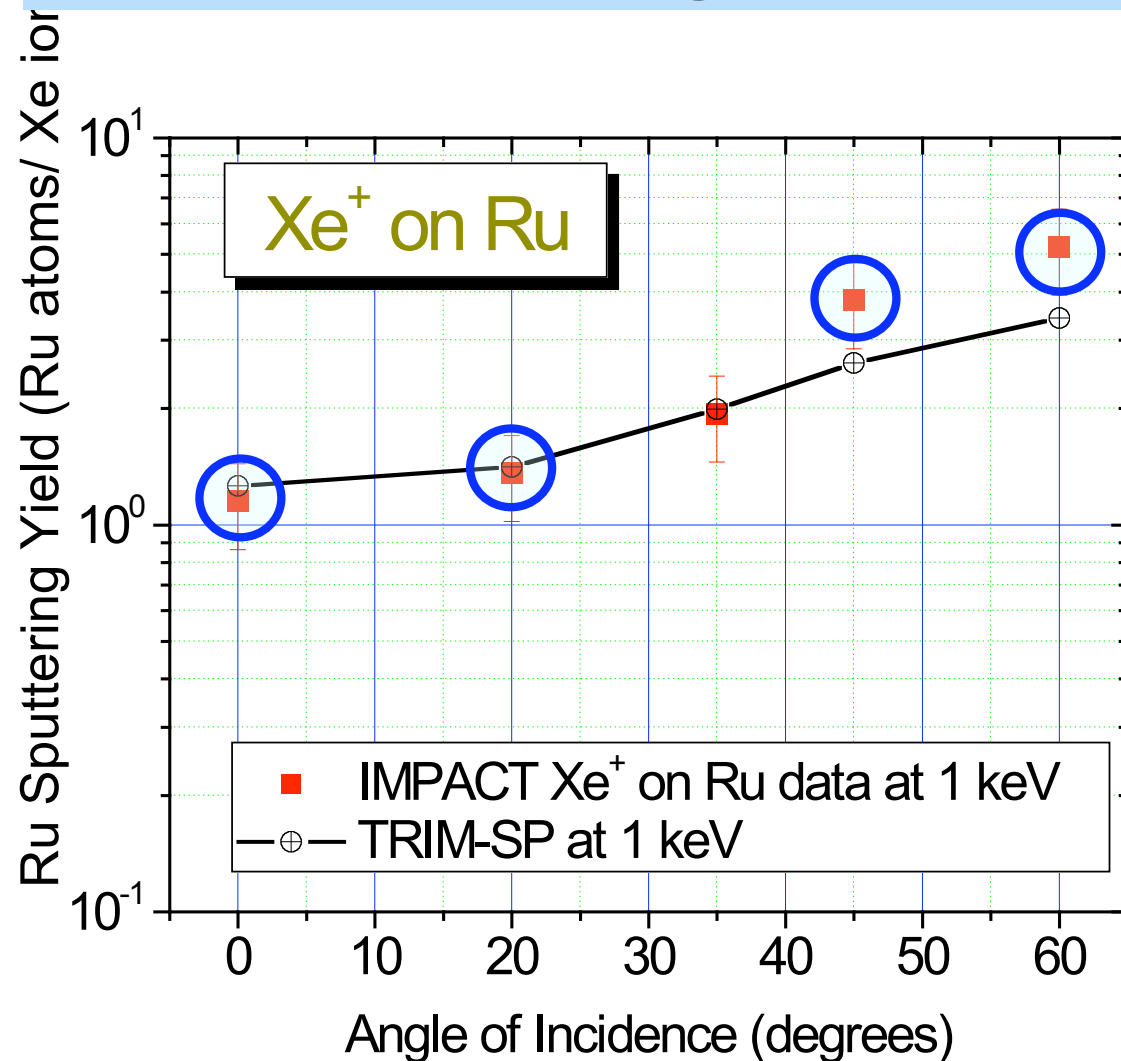
Xe⁺ Irradiations of Ru and Pd single-layer mirrors

- **IMPACT is capable of measuring depth profiles using: ISS, AES or XPS.**
- **IMPACT measures the erosion rate needed to convert from time scale to spatial scale in real-time.**
- **We have studied for example, the evolution of oxygen in Ru and Pd-based systems where also a complex mixing zone is found.**
- **Our ion sources are versatile so that we operate at minimal destruction fluxes for characterization (10-100 nA).**

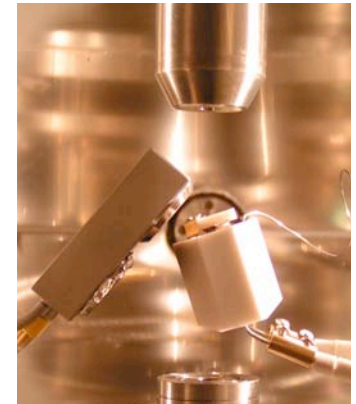


IMPACT is \$ 1M facility funded with non-fusion \$\$ and is already making a contribution to the fusion PFC community

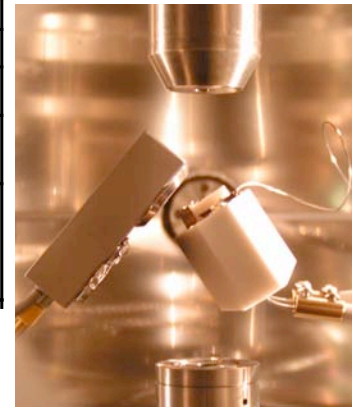
Ru sputtering at oblique incidence



$\theta = 0^\circ$



$\theta = 20^\circ$



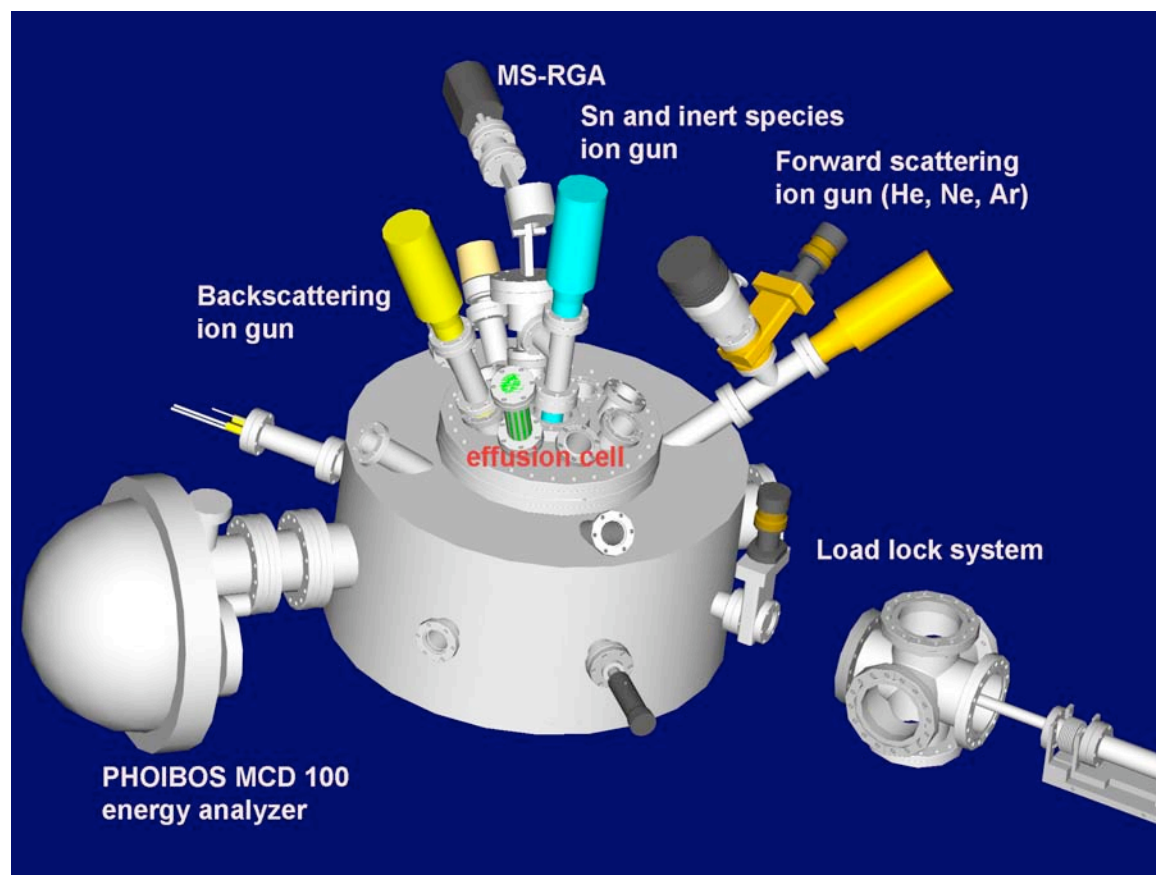
$\theta = 45^\circ$



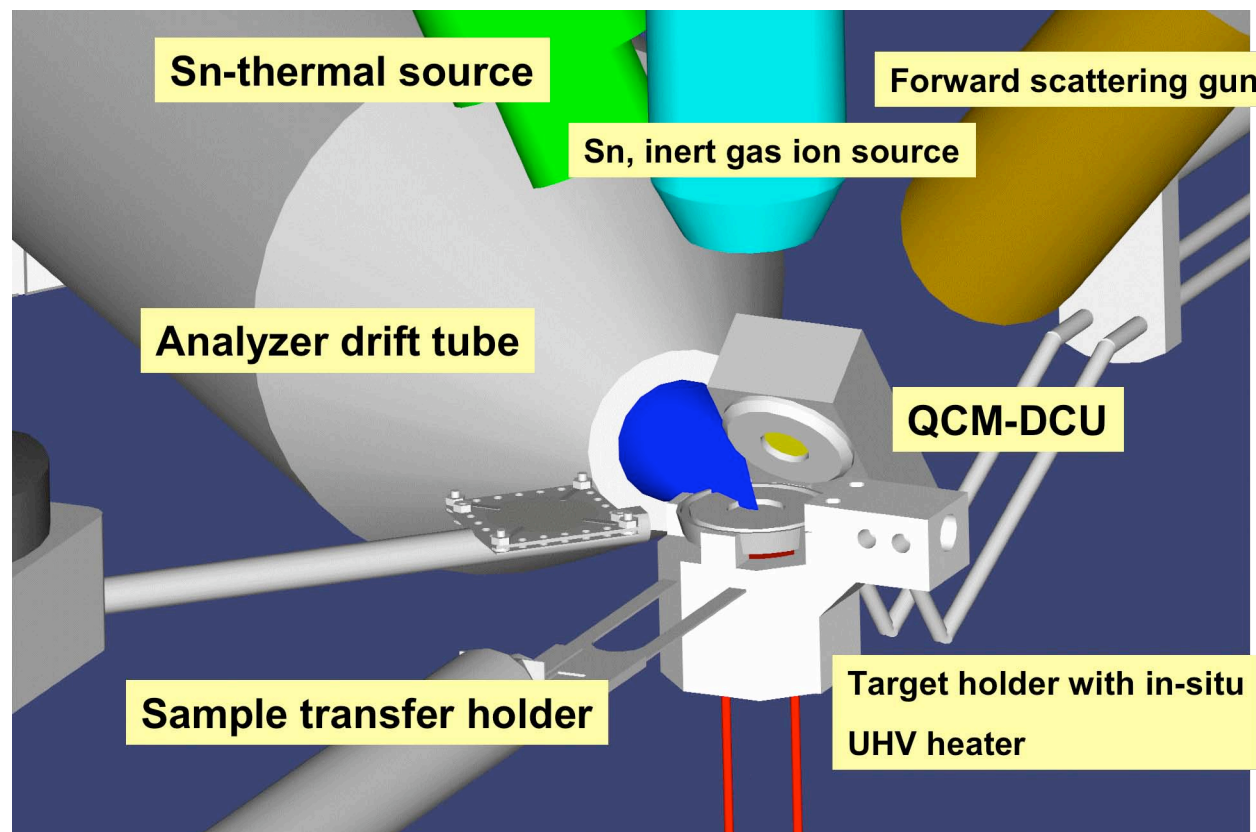
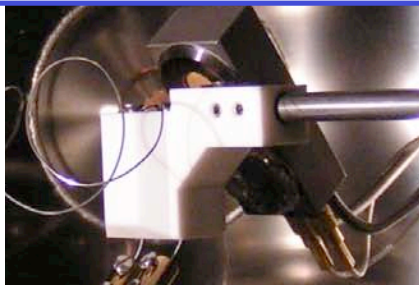
$\theta = 60^\circ$

IMPACT Experiment Setup

- Singly-charged particle source providing flux range from 10^{11} - 10^{17} ions/cm²/sec and Energy: 10-5000 eV.
- Xe, Li and Sn ion sources as well as: He, Ne, Ar, Kr, O, H, D, N
- In-situ heater (25-500 °C) on rotary manipulator for angle-of-incidence studies.
- We will procure an e-beam evaporator compatible with Be for these studies
- IMPACT in addition has a separate chamber for temperature desorption spectroscopy analysis



IMPACT In-situ metrology

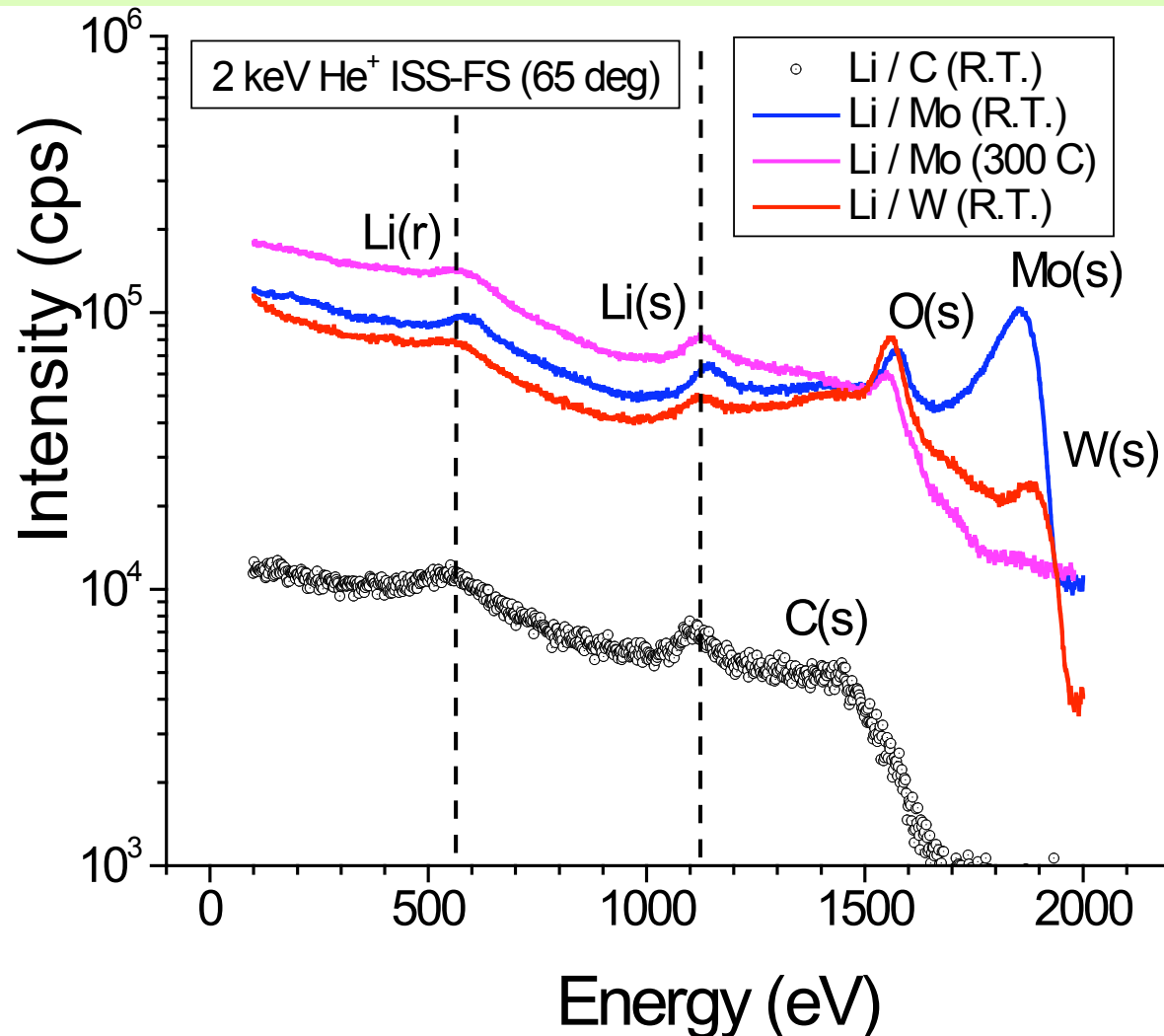


- Dual quartz crystal microbalance for total erosion measurements.
- **In-situ Metrology:** Low-energy ion scattering spectroscopy (forward and backward scattering), direct recoil spectroscopy, Auger electron spectroscopy, X-ray photoelectron spectroscopy using a SPECS 100-MCD.

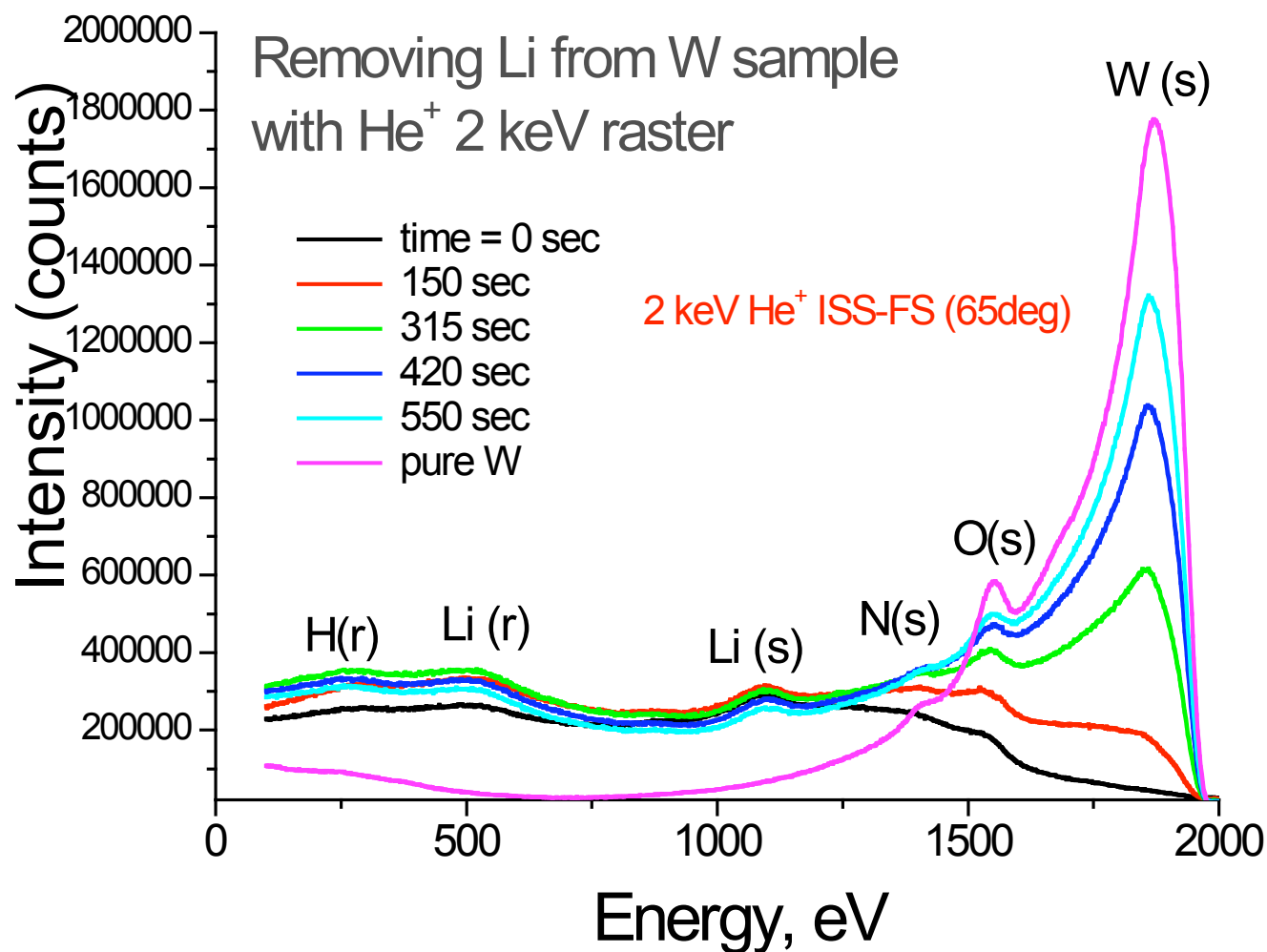
Angle-resolved ion energy spectrometer (ARIES) at SNL/CA

- Experiment designed to provide detailed top atomic layer analysis of thin films and materials (angularly-resolved low-energy ion scattering spectroscopy and Auger electron spectroscopy)
- **The system has two sections:**
 - A low-energy (0.1 – 3 keV) ion source differentially pumped chamber
 - UHV analysis chamber ($P \sim 10^{-10}$ Torr)
- **ATJ graphite samples polished and annealed were prepared with various coatings.**
- In addition, W and Mo substrates were also coated with 300 nm Li and selected samples were delivered to ANL.
- **ISS, AES and SEM analysis of samples.**

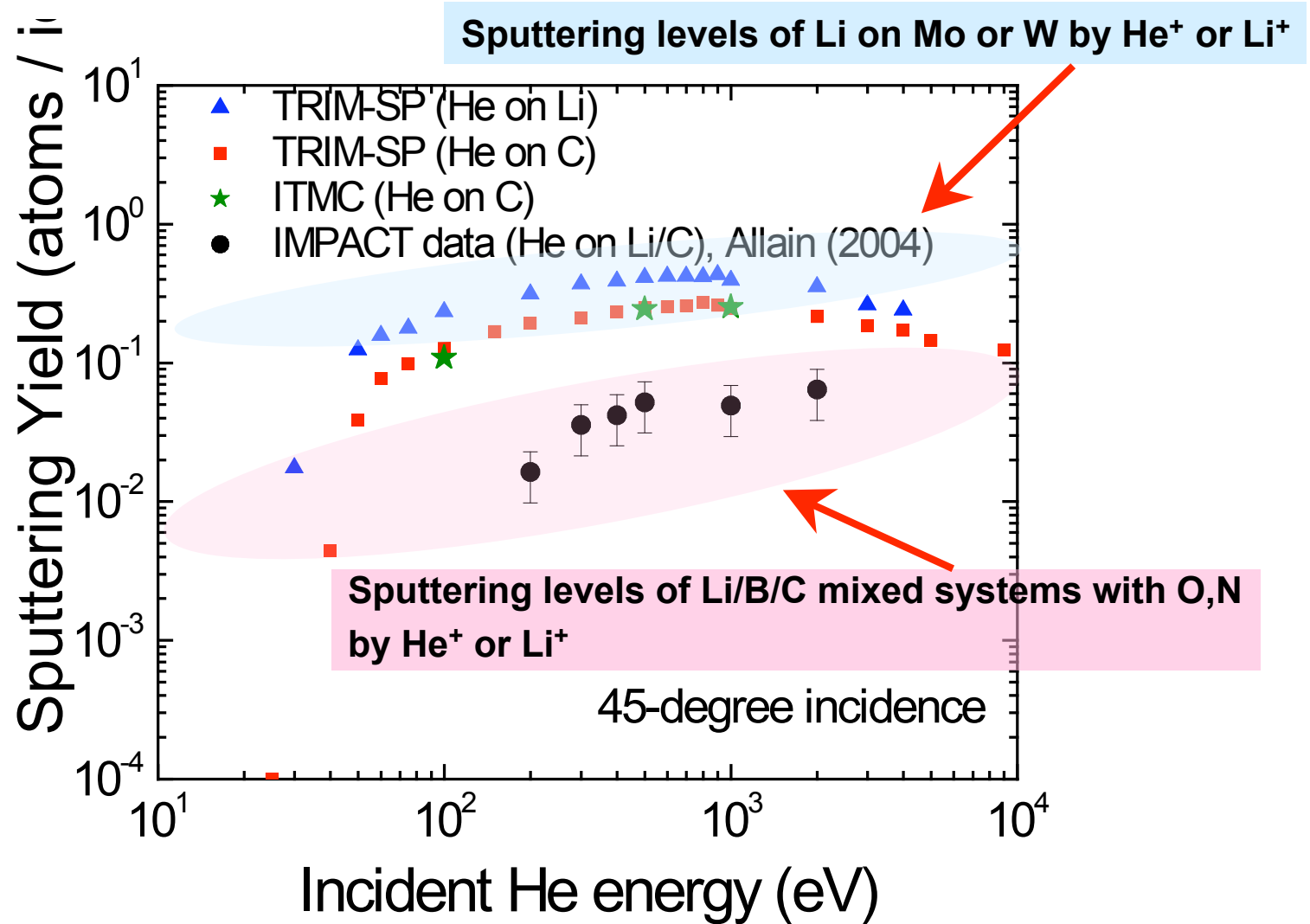
IMPACT results shows a complex mixed layer on surface of Li/C systems



Removal of Li layer from W



He⁺ and Li⁺ on ATJ graphite



Tasks for proposed work

- Sample preparation of Be/C samples will be prepared by J.P. Allain at ANL using an e-beam evaporator system for Be. In addition 1-inch samples exposed in PISCES-B will also be analyzed/tested at ANL.
- Study surface evolution under controlled bombardment conditions with He^+ and D^+ on a mixed Be/C sample at room temperature and 473 K for incident particle energies at 50, 100 and 1000 eV. Coordinate work with R. Doerner of UCSD.
 - Bob Bastasz will visit ANL to conduct experiments with J.P. Allain
- Monitor carbon erosion after deposition of a given Be atom flux while using ISS, AES and XPS to monitor the surface atomic concentration evolution.
- Study D ion and atom interaction with mixed Be/C surfaces using ARIES at SNLL as a function of temperature.
 - J.P. Allain will visit SNLL to conduct experiments with R. Bastasz

Budget and Work Plan

Experimental Tasks	Jan-Mar			Apr-Jun			Jul-Sep		
Be-C mixed materials preparation									
Erosion studies of mixed Be/C under D ⁺ and He ⁺ impact									
Surface evolution studies in ARIES									

- **Personnel:** J.P. Allain, M. Nieto at ANL **60 K**
- **Equipment:** e-beam evaporator system **20 K**
- **R. Bastasz at Sandia Livermore** **20 K**
- **Collaboration with R. Doerner** **from base program**
- **Total: \$ 100 K for FY 2005**